

# Technology and Teaching Children to Read

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The Building Blocks of  
an Effective Elementary  
Reading Program  
p.2  
.....

A Framework for  
Technology to Support  
Reading Instruction  
p. 2  
.....

Technology and the  
Building Blocks for  
Teaching Children to Read  
p. 5 - 15

Phonemic Awareness p. 6

Phonics p. 8

Fluency p. 10

Vocabulary p. 11

Text Comprehension p. 12  
.....

Other Potential Benefits  
of Technology in Reading  
Instruction  
p. 15  
.....

Making Decisions about  
Technology in Reading  
Instruction  
p. 17  
.....

Conclusions  
p. 19  
.....

Appendices  
p. 21 - 24

Appendix A p. 21

Appendix B p. 24  
.....

Bibliography  
p. 25

# Technology and Teaching Children to Read

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A significant base of research, developed over many years, is available to inform educators about effective approaches to teaching children to read. However, research on the use of multimedia digital technologies to enhance reading instruction is in its infancy. This reflects the fact that the technological capabilities that appear to have the most potential in helping children learn to read, such as computer speech recognition, have only recently become sufficiently affordable and available for widespread use. New products using these technologies have recently been announced, more are on the way, and a number of research studies are underway to test the impact of these products on children's learning.

This report is intended to provide background information that will help reading specialists, education technology specialists, classroom teachers, and special education teachers work together to understand, evaluate, and implement effective uses of technology within K-6 reading programs. It brings together the research-based guidelines for teaching children to read from the National Reading Panel report (NRP, 2000) with information about the potential uses of multimedia digital technology to enhance reading instruction. It provides background about effective reading instruction and potential uses of technology, and summarizes the currently available research evidence on ways in which technology can successfully enhance reading instruction in the elementary grades.

In order to make best use of the information presented in this report, technology and reading specialists might want to consider the following set of questions together in preparation for making decisions about technology in reading instruction.

## Key Questions to Consider about Technology and Teaching Children to Read

1. Is a process established in your school or district for reading specialists, technology specialists, classroom teachers, and special educators to collaborate on reviewing the possibilities and recommending uses of technology to enhance reading instruction?
2. What technologies (hardware and software) are available in your school or district to support reading instruction? How are they currently being used? How are teachers prepared to use them effectively?
3. Which of the five components of effective reading instruction (phonemic awareness, phonics, fluency, vocabulary and comprehension) need to be strengthened in your school or district? Which technologies can enhance these components?
4. How is your school providing reading instruction to students who are reading below their grade levels? ESL students? Special needs students? How can technology support teachers in helping these students?
5. Is information being provided to parents about how technology can help their children learn to read both at school and at home?



Note that this report focuses on technology to help children in the elementary grades learn to read. It does not address many other important issues about the impact of technology on literacy, such as what it means to be information literate in the 21<sup>st</sup> century. Nor does it address the role of technology in language arts in general, or in reading beyond the elementary level.

## The Building Blocks of an Effective Elementary Reading Program

At the request of the U.S. Congress, the National Reading Panel conducted an extensive review of the research on teaching children to read and, in 2000, issued its report on the research-based components of effective reading instruction. The panel concluded that an effective approach must contain the following five components:

1. *Phonemic awareness instruction* to help children learn to segment speech into individual sounds (phonemes) and to blend sounds to form words. The ability to work with speech sounds in these ways is an essential foundation for phonics instruction.
2. *Phonics instruction* to teach children the relationships between sounds and letters. Phonics skills help children recognize words and decode new written words to their spoken forms.
3. *Fluency instruction* to help children learn to read text with speed, accuracy, and proper expression. Fluency is a critical component of learning to comprehend text.
4. *Vocabulary instruction* to increase the number of words for which children know the meanings. This includes helping children understand that a given word can have different meanings depending upon the context.
5. *Text comprehension instruction* to help

children develop purposeful and active strategies for understanding what they read. These strategies include monitoring children's understandings as they read, generating and answering questions about the text, and summarizing important ideas from the text.

These five components need to be integrated as children learn to read. For example, students who cannot recognize or decode written words, cannot read fluently, or don't understand the meanings of words, will be limited in their text-comprehension abilities. Reading meaningful texts at appropriate levels of difficulty is one way for children to increase their vocabulary and practice their phonics skills. To construct meaning from written texts, skilled readers bring together all the components of reading in combination with their prior knowledge about what they are reading.

## A Framework for Technology to Support Reading Instruction

Before elaborating upon the five building blocks of reading instruction and examining the potential uses of technology for each one, we will provide a general framework of multimedia computer capabilities that can be employed to help children learn to read. Note that this framework for technology is based upon a critical assumption: *Knowledgeable and dedicated teachers are the critical element in successful reading instruction programs.* While technology can support these teachers and help them be more successful with all children, it can never replace qualified teachers because teaching children to read is too complex — it requires insight into children's cognitive abilities and emotional needs, and is dependent upon the types of reinforcement, guidance, and support that can only be provided by caring, knowledgeable teachers.

The technology framework consists of four general capabilities that computers can



provide to support students learning to read. Computers can:

- present information and activities to students;
- assess students' work;
- respond to students' work; and
- provide *scaffolds*, such as access to word pronunciation and definitions, that help students read successfully

These four key capabilities, whether supplied by teachers using traditional materials, such as books and audiotapes, or by computers, have proven to be important components in reading instruction. Computers can now provide each of these capabilities to support teaching and learning in new ways, as is described in the following section. For examples of specific software that provide these capabilities to support reading instruction, see *Learning to Read in the Computer Age*, by Anne Meyer and David Rose (1998)

### ***Present information and activities***

Multimedia computers can present any type of auditory or visual materials—including speech, text, music, animations, photographs, or videos—alone or in different combinations. They can link different types of representations such as pictures with sounds, oral readings with written text, videos with subtitles, or any other combinations that might reinforce teaching and learning. They can also provide enormous flexibility, allowing the user to set the speed of speech, decide whether written text is also read aloud, choose the language presented in text and speech, or decide whether to repeat the presentation. This flexibility can be valuable in presenting educational tasks—such as phonemic awareness practice, phonics lessons and drills, fluency practice, vocabulary instruction, and opportunities to learn and

apply text-comprehension strategies—to students.

### ***Assess students' work***

Computers can accept a variety of inputs from students, ranging from mouse clicks to written text to spoken words. (A wide variety of special input devices, such as touch screens, special keyboards, and single-switch devices are also available for young children and students with special needs.) Computers can be programmed to check a child's work to determine whether he or she selected the correct word or picture, typed a correct word, said the correct word, or, with recent advances in computerized speech recognition, read a passage fluently.

Computers are, of course, highly capable of recording and organizing information, and reporting that information in multiple formats. Computers can, for example, record the responses of all students in a class to a set of letter-sound matching problems and then immediately report to the teacher the errors made by each individual student and the most common errors made by the entire class. In more complex tasks involving oral reading or text comprehension, computers can serve as convenient recording and reporting devices for teachers, helping them track student progress far more conveniently than other means of data collection. This capability can be used to inform teachers' instructional decisions and to make documenting students' progress more efficient.

### ***Respond to students' work***

Effective instruction needs to be interactive — when children respond to questions or read aloud, they need feedback to know whether they are correct, instruction to help them learn more, and opportunities to engage in additional work at appropriate levels to further their learning.



In terms of responding to students' work, computers have both some limitations and some advantages over teachers. When tasks require simple inputs, such as selecting from presented options or typing a word, computers can be programmed to immediately evaluate each response and provide appropriate feedback. This feedback can be in the form of positive messages when the child is correct, and hints, additional chances, or corrected answers when the child is incorrect. Most importantly, computers can be programmed to adjust the task presented to be based on feedback from previous performances. For example, a phonics instruction program can analyze a child's pattern of correct and incorrect responses and provide that child with practice on the specific letter-sound correspondences that he or she has not yet mastered. A comprehension program can assess a child's responses to an initial set of comprehension questions and, depending upon the child's level of success, provide easier or more challenging text and questions. New products are able to assess students' oral reading as they read and provide immediate feedback such as pronouncing words on which the child hesitates or mispronounces. (While the ability to have computers understand and respond to students' language in both text and spoken forms has advanced significantly in recent years, it is still far more limited and far less flexible than what a teacher can provide.)

### ***Provide scaffolds that help students read successfully***

A skilled reader uses multiple cues in reading simultaneously — recognizing familiar words, using word patterns and meanings to group words into meaningful clusters, using prior knowledge and context to understand the meaning of the text, and applying text-comprehension strategies. In learning to read, these processes should be interconnected; a child should apply phonics in

reading text and in writing, learn vocabulary in the context of reading meaningful text, and read fluently in order to comprehend successfully.

As a child is learning, the multifaceted requirements of reading can cause “cognitive overload,” in which there are too many competing demands for the child to succeed in reading fluently with comprehension. For example, children who struggle to decode the individual words of a story will devote all of their attention to the individual word level, and therefore be unsuccessful in understanding the events in the story.

Teachers strive to select appropriate reading materials, pose appropriate tasks, guide students' practice, and adjust instructional interactions to provide an appropriate level of challenge—neither so easy that it leads to boredom nor so difficult that it leads to frustration—for each student. For complex tasks, teachers provide scaffolds that enable children to engage successfully in reading with comprehension. For example, teachers may read a text aloud before asking children to read it on their own, review new vocabulary words before asking children to read a passage aloud, and provide immediate help when the child hesitates on or misreads a word.

Scaffolds for learning to read are analogous to training wheels for a child learning to ride a bicycle. Training wheels let the child experience getting around on a bicycle while focusing on pedaling and steering. Reading scaffolds let children experience interesting stories on their own, while providing opportunities to continue mastering phonics, vocabulary, fluency, and comprehension. Teachers must also make instructional decisions about when to reduce the scaffolding and have children be responsible for reading without them—analogous to deciding when the novice cyclist is ready to try without the training wheels.

Computers can provide powerful scaffolds



or “training wheels” for children’s reading by presenting information flexibly, assessing students’ work, and responding to students. For example, a student with limited phonics skills or vocabulary can benefit from scaffolding in the form of an online dictionary that, at the click of a mouse, can speak the word and display its meaning. Similarly, students who have difficulty chunking sentences into meaningful phrases—a critical component of fluent reading—can have the computer highlight text in meaningful chunks to provide models of how words are grouped for fluent reading. Or a child weak in comprehension strategies can be guided by the computer to pose and answer questions, create concept maps, or check his or her own understanding while reading on-screen text. New technologies enable computers to provide immediate help when children need it in oral reading. The role of the computer is to make individualized, responsive scaffolds available for each child—providing, as close as possible, what a teacher would provide when working individually with a student.

### **Technology and the Building Blocks for Teaching Children to Read**

The National Reading Panel reviewed the current research on technology and reading. As in all of its reviews, the panel considered only those research studies that met stringent design criteria and included control group or baseline comparison measures in hopes of providing evidence of causal connections between teaching methods and student learning. Because computers available in schools have only recently reached high levels of performances for multimedia, speech recognition, text analysis, and networking, there has not yet been time to conduct the studies necessary to build a solid research base on the many ways in which technology can support reading instruction. Because this is a relatively new field, the number of studies published in this area is small—for example, only 21 studies

met the NRP research methodology criteria required for consideration. However, all of these studies reported positive results, suggesting that the use of computer technology to enhance reading instruction is worth careful consideration. In particular, the NRP notes seven studies found positive effects from the capability of computers to provide spoken versions of written text, which indicates that this may be a promising use of technology in reading instruction. The panel also reports that the use of hypertext (text that allows the reader to select different paths, such as links to definitions, clarifications, or elaborations) and word processing show promise, but that sufficient research is not yet available to draw firm conclusions on these or the many other possible uses of technology to enhance reading instruction.

Our review extends the work of the National Reading Panel in this area. We organize our analysis in terms of the five major building blocks of effective reading instruction described above. For each component, we summarize some of the research-based teaching recommendations, potential uses of technology to support these recommendations, and currently available research on these uses of technology. The teaching recommendations presented here are based largely on the *Put Reading First: The Research Building Blocks for Teaching Children to Read* report (Armbruster and Osborn, 2001), which summarizes the implications of the National Reading Panel report for classroom practices. A concrete set of examples linking teaching recommendations and potential uses of technology are summarized in the table in Appendix A.

We use the NRP criteria of including only those research studies that examined instructional uses of technology and tested these uses with experimental or quasi-experimental methods. However, we broaden the reviews to include studies of special education populations reading at the K-6 level that meet the research





quality criteria. Our review covers research published from 1987 to 2002, therefore including studies that were not included in the NRP review. We did exclude studies in which we considered the technology to be obsolete and therefore lacking relevance to decisions about currently available technologies. For example, early speech recognition technologies were so limited and unreliable, that research on these should not be used to inform decisions about the use of the far more powerful speech recognition technologies available today. The list of resources reviewed is provided in Appendix B.

### Phonemic awareness

Phonemic awareness, typically a focus in grades K and 1, is the ability to notice, think about, and work with the individual sounds of spoken words—for example, to know that “cat” consists of three sounds, /c/, /a/, and /t/; that the first sound matches the first sound of “cake” and that the last two sounds match those of “hat”, “rat”, “bat”, and “that.” Understanding that words are made up of speech sounds, and being able to compare sounds in different words, divide words into constituent sounds, and blend sounds together to form words, all form an important foundation for learning to read. Note that the word “phoneme” refers to the individual sounds of language, and that “phonemic awareness” is about awareness of speech sounds separate from written forms of language. One could have phoneme awareness without ever encountering a written language.

### Teaching Recommendations

- Use activities in which children work with the sound of words in a variety of ways, such as: *blending* sequences of spoken sounds to form a word, as in blending /b/ /i/ /g/ to form the word **big**; *segmenting* words into separate sounds, for example, in which they segment **big**

into its three constituent sounds, /b/ /i/ /g/; *adding* sounds, as in adding /s/ to “mile” to make “smile”; *substituting* sounds, as in change /r/ in “run” to /b/ to form “bun”, and other activities involving identifying, matching, and altering the sounds of words.

- Adjust activities to the child’s level of phonemic awareness. For example, identifying initial sounds is easier than identifying all the sounds in a word.
- Teach sounds along with the letters of the alphabet to provide a bridge between phonemic awareness and phonics.
- Use small-group instruction whenever possible so children can both benefit from listening to their classmates respond and receive feedback from the teacher.

### Technology

Computers can present a variety of phonemic awareness practice activities and provide feedback to students and reports to teachers about students’ progress. Multimedia presentations can address many different learning styles by integrating sound, text, and moving images. These presentations can also accept input from a variety of sources by letting students enter responses by pointing, typing, or speaking. For example, many software programs for young children incorporate matching activities in which students are asked to match a sound with pictures of objects that start with that sound, a sequence of sounds with the word they form when blended together, or pictures of objects with names that start with the same sound or which rhyme. In these types of activities, many of the capabilities of computers described above can be employed to:

- provide tasks that involve both segmenting words into sounds and blending sounds into words;



- provide immediate feedback to let students know whether their answers were correct, give them hints or additional chances, and provide correct answers;
- individualize problem sets to focus on the phonemes that the student has not yet mastered;
- repeat activities and alter the speed of speech to meet individual needs;
- provide activities that ask children to match sounds and letters;
- provide activities designed for two or three children to work together;
- provide game contexts, attractive visual presentations, and motivating speech, to engage and hold children's interest;
- provide reports for teachers and children's progress and areas in which individual children need additional work; and
- engage children in productive self-directed work on phonemic awareness while the teacher works directly with other children, thereby helping the teacher meet the individual needs of each student.

### Research

Several research studies have shown positive results of using software with text-to-speech capabilities designed to help young children develop phonemic awareness and, in some studies, phonics abilities. In one study (Mitchell and Fox 2001), kindergarten and first-grade students who were at-risk for reading problems received software intervention on blending phonemes. The results show that these students improved their skills as much as a group of peers who worked directly with a teacher. A third group of students who received no intervention failed to show any notable improvement.

Students at the two grade levels responded equally well to the software, indicating that it is not necessarily essential for students to begin working with such software in the first year of reading instruction.

A similar study in the Netherlands (Reitsma & Wesseling 1998) noted that primary school children who received phonemic awareness instruction through a software application significantly outperformed classmates who received no instruction, and performed on par with or slightly below a group of classmates who worked directly with the teacher during this time. Additionally, students who received instruction from both the teacher and the computer improved significantly more than those students who worked only with the teacher, indicating that the computer could be effective as a supplement to the teacher.

Another study of Dutch kindergarteners found that children who practiced with a software application designed to teach blending and reinforce phonemic awareness instruction could read more words and identify letters more readily than peers who did not use the software (van Daal & Reitsma 2000). Similarly, in a U.S. study of first-grade students who used a software application with text-to-speech capabilities designed to support the development of phonemic awareness, children in the experimental group outperformed their peers in both the specific skills the software was explicitly drilling and in their consequent ability to identify and read words (Barker and Torgesen 1995).

These studies suggest that there is good potential to using technology to support phonemic awareness and phonics instruction by providing increased opportunities for students to practice blending phonemes and segmenting words. However, research has not yet determined the most effective ways to design and use software that provides these capabilities, thus educators are left to judge whether the software makes good





use of the capabilities of the technology, follows the principles of effective phonemic awareness instruction, and provides a good fit to the overall reading instructional approach used.

### **Phonics**

Phonics instruction focuses on the letter-sound correspondences so that children learn that the three sounds of “cat” correspond to the three letters, **c**, **a**, and **t**. Knowing the relationships between written letters and spoken sounds helps children recognize familiar written words and decode new written words so they can apply their knowledge of the spoken words. While the English language contains many irregularly spelled words that don’t follow the standard letter-sound correspondences, most of these words contain some regular letter-sound relationships, and knowledge of phonics supports children’s memory for specific words. Phonics is typically a major focus of reading instruction in grades K-2, but is best combined with the other components.

#### *Teaching Recommendations*

- Explicitly teach children the letter-sound relationships, including consonants, vowels, and larger units of language (for example, th, ea, ing) in a clearly defined sequence.
- Adapt phonics instructions to the needs of individual students based upon assessments of their knowledge of letter-sound correspondences.
- Combine phonics instruction with phonemic awareness activities, learning to recognize and write the letters, listening to stories and information texts read aloud, reading simple text, and writing. Make sure to select materials that contain many words that students can decode with the phonics they have learned.

### *Technology*

Many of the capabilities of computers for phonics instruction overlap those already described for phonemic awareness instruction. In fact, many of the software applications that support phonics development also make use of additional scaffolding to enable phonics practice to be integrated with reading meaningful text and with students’ writing. Potential uses of technology to enhance phonics instruction include the ability to:

- provide tasks that involve students matching sounds and letters, and spoken and written words. In some cases, this simply involves adding letters and a written word component to phonemic awareness activities;
- provide immediate feedback to let students know whether their answers were correct, give them hints or additional chances, and provide correct answers;
- individualize problem sets and present stories to focus on the letter-sound correspondences and words that the student has not yet mastered;
- provide as many repetitions as necessary and alter the speed of speech to meet individual needs;
- provide game contexts, attractive visual presentations, and motivating speech, to engage and hold children’s interest;
- provide reports for teachers’ and children’s progress and areas in which individual children need additional work;
- provide texts for children to read with scaffolds to support phonic skills—for example, software can enable a child to click on any word and hear the individual sounds of the word or the whole spoken word; and



- engage children in productive self-directed work on phonics while the teacher works directly with other children, thereby helping the teacher meet the individual needs of each student.

### Research

Software specifically designed to drill students on consonant and vowel letter-sound relationships may make use of a number of computer capabilities, including visual highlighting and synthesized speech. When appropriately designed and used, this software can have a substantial impact on student learning (Grabe and Grabe 1996). In most classrooms, instructionally appropriate drills can supplement teaching very effectively, and may, in fact, be convenient tools in helping students develop fluency and accuracy in word identification (Burns, Roe & Ross 1996).

Several studies have shown positive results of technology to support phonics instruction with young children. Beginning readers in the Netherlands substantially improved their rate and accuracy of word identification after working with software that offered digitized pronunciation of words (Reitsma 1988). In a study of first-grade students who used a software application with speech capabilities, children in the experimental group outperformed their peers in both phonemic awareness and in their consequent ability to identify and read words (Barker and Torgesen 1995).

Some phonics software helps develop children's understanding of word segmentation by breaking the word into recognizable components visually or audibly. Several studies have found positive effects of this type of software on students' learning. Wise, Olson, and Treiman (1990) found that first-grade students who used software with visual highlighting and synthesized speech improved in their abilities to blend words after hearing them segmented at the

onset-rime (first sound-rest of word) level. When the children later encountered these words in other contexts, they were able to identify them readily. Wise (1992) found that a word segmentation drill that also used visual highlighting and speech feedback proved extremely effective in enhancing whole-word and syllable recognition among emergent readers. Although teachers sometimes express concern that such tools will become a crutch, eight-year-old students using hypertext pronunciation aids relied less and less on the feature as they became more sure of the text (Miller, Blackstock, & Miller 1994). These studies support the idea that computers are able to combine text-to-speech capabilities with visual material to create a unique resource to support and enhance traditional methods of phonics instruction.

Upper elementary students with reading difficulties may also have much to gain from software designed to drill phonics; for students at lower reading levels or with learning disabilities, these gains have been shown to be especially significant (Olson, Wise, Ring, & Johnson 1997). One such study (Jones, Torgesen, & Sexton 1987) found that American ten-year-olds with learning disabilities made substantial improvements in medial vowel identification after practicing with a vowel program. In addition, the students were able to use the skills they learned to identify words that did not appear in the program. An earlier study of similar software (Roth & Beck 1987) involved fourth-grade students at various reading levels and found that low level readers could visually identify more medial vowels and could blend onset-rimes more effectively after using a software application that drilled them on these skills.

Research has not yet established the value of digital speech to scaffold students reading and writing in ways that support their learning of phonics. One initial study exploring the use of talking word processors and story tools with preschool



children found that their spelling improved, indicating that they were more aware of the associations between letters and sounds (Moxley, Warash, et al 1997). However, Jones (1998) found that the speech features of such software often hold little appeal for young children who do not yet grasp the connection between words and sounds, raising questions of when and how these types of supports could best be used. Most of the research on the use of talking story books focuses on vocabulary, fluency, and comprehension, though Lewin (1997) found positive effects of these on children's word decoding strategies as well. Additional research is necessary to provide evidence and guidance about the use of technology to support embedding phonics instruction in students reading and writing of meaningful text.

### **Fluency**

Fluency is the ability to read a text accurately and quickly with appropriate pacing and intonation. Fluent readers read aloud effortlessly and with expression, as if they were speaking, while readers who are not yet fluent read slowly, word by word. To read fluently and with expression, readers must be able to easily recognize or decode individual words and divide the text into meaningful phrases and clauses. Fluency provides a bridge between word recognition and comprehension. Children who cannot read texts fluently often have trouble fully comprehending the material.

#### *Teaching recommendations*

- Model fluent reading and then have students read the same text aloud.
- Provide guidance and feedback during repeated oral reading in order to improve word recognition, speed, and accuracy as well as fluency; Oral reading with support (for example, help with unknown words) and feedback provides more effective practice to increase fluency than silent, independent reading.
- Increase oral reading practice through the use of audiotapes, tutors, peer guidance, or other means that provide both modeling of fluent reading and feedback.
- Give students books in which they can read 95% of the words; Fluency develops as a result of many opportunities to practice reading with a high degree of success.

#### *Technology*

Electronic books, or e-books, present traditional picture book text and images in an alternative on-screen format. The simplest electronic books simply transfer the story from paper to the screen, and allow the child to listen as the program reads the story aloud. Some e-books may also highlight each word as the child progresses through the book. More complex electronic books create a more malleable story, allowing children to manipulate the text and introduce features not found in traditional books (Labbo & Kuhn 1998).

E-books, with features designed specifically to support children learning to read fluently, can provide multiple supports for fluency instruction, including the ability to:

- provide a model of fluent oral reading;
- provide on-demand or automated help in decoding individual words, so that a problem with a few words does not disrupt the child reading;
- provide visual highlighting of phrases to guide the child in learning to read with expression;
- allow beginning readers to tackle more varied and challenging texts with additional support for pronunciation and



meaning, thereby allowing them to “read” on their own more successfully and gain additional experience with text;

- provide speech recognition tools so that students can get immediate help while reading aloud; and
- provide recording and analysis tools for teachers to help them assess students’ levels of fluency and to inform instructional decisions.

### *Research*

The fluency of oral reading has not been the focus of research on the uses of technology to enhance reading instruction, although some of the research on phonics, vocabulary, and comprehension measured changes in students’ abilities to read out loud. With the recent advances in computerized speech recognition, new tools and products designed to assess and provide useful feedback about children’s oral reading are becoming available, and research on the effectiveness of these tools is underway.

### **Vocabulary**

Vocabulary instruction focuses on students expanding the breadth and depth of vocabulary knowledge. Reading specialists refer to oral vocabulary, the words one knows in speech, and reading vocabulary, the words one knows in print. Beginning readers use their oral vocabulary to make sense of the words they see in print, and thereby extend their reading vocabulary. As they begin to read, they learn the meaning of new words that are not part of their oral vocabulary through direct instruction, using dictionaries, and through the use of the context in which they read the words.

### *Teaching recommendations*

- Encourage activities that support vocabulary growth. Children learn

the meanings of most words indirectly, through everyday experiences with oral and written language, including conversations with adults, listening to adults read to them and discussing unfamiliar words, and through reading extensively on their own.

- Teach key vocabulary words directly, for example by reviewing new vocabulary words in a text before students read the text.
- Provide lessons on difficult words, such as words with multiple meanings, words that are spelled alike but pronounced differently, and idioms.
- Teach word learning strategies, such as the use of the dictionary and thesaurus; the use of suffixes, prefixes, and roots; and the use of context clues to figure out the meanings of words.
- Have students make repeated use of new words in different contexts, including reading, discussions, and writing.

### *Technology*

The teaching recommendations suggest several ways in which technology can support vocabulary development in children, including the ability to:

- provide online, interactive vocabulary lessons, with the features to engage students, provide feedback, individualize instruction, and keep records for teachers;
- provide online dictionaries, thesauri, and encyclopedias, with speech capabilities, to give students access to tools to use with their word learning strategies;
- provide online texts with hyperlinks that give students definitions of words and further information about key ideas in the text; and



- provide students with additional opportunities to extend their vocabularies by increasing the amount of reading and writing they do through the use of online materials and exchanges. Examples of such opportunities include websites, discussions, online publishing, web logs, and other technology-enabled uses of text.

### *Research*

In one study of direct vocabulary instruction, Jones, Torgesen, & Sexton (1987) found that children who work with software applications specifically focused on building vocabulary developed better strategies for identifying words that do not appear in the program, indicating that these programs help children acquire word learning strategies, not just the meaning of the specific words taught. A number of studies at different grade levels have found positive impact on students' vocabulary learning to result from the use of electronic talking books and electronic texts with scaffolds to support vocabulary development. Students in a multi-age primary classroom were able to use hypermedia and hypertext features to read books above their reading levels and also showed significant gains in vocabulary (McKenna & Watkins 1996). At-risk readers also scored higher on vocabulary tests after using electronic textual aids (Anderson-Inman & Horney 1998). Studies of upper elementary and middle school students show marked improvement in vocabulary and text comprehension in students who used electronic texts in place of traditional print-based texts (Reinking & Rickman 1990). The research on hypertext described in the comprehension instruction section below is also relevant to vocabulary learning, since it involves engaging students in active reading, which can enrich vocabulary.

### **Text Comprehension**

Text comprehension instruction helps children develop purposeful and active

strategies for understanding what they read. This includes learning to monitor their own comprehension to be aware of what they do and do not understand, and to know how to resolve problems in comprehension. All the prior components are critical parts of text comprehension—students who cannot recognize or decode written words, cannot read fluently, or don't know the meanings of words will be limited in their abilities to comprehend text. Text comprehension instruction also includes teaching a variety of strategies that have been shown to increase understanding and recall, such as generating questions about the text, predicting what will happen next, summarizing ideas, forming mental pictures while reading, and comparing prior knowledge to the information in the text.

### *Teaching recommendations*

- Help students to monitor their comprehension for self awareness of what they do and do not understand, and ensure that they have strategies to reread and further their understandings.
- Encourage students to use graphic and semantic organizers, such as concept maps and other conceptual organizers, to help focus on the concepts in a text and relationships among those concepts.
- Help students to generate questions and seek answers to their questions in the text, which sets purposes for reading, focuses attention on what is learned, encourages comprehension-monitoring, and helps relate new information from the text to prior knowledge.
- Teach students to recognize the structure of stories so they can place what they are reading into a coherent framework of elements such as the setting, initiating events, internal reactions of characters, goals, attempts, and outcomes.
- Guide students to summarize the information they read as a way of





monitoring comprehension and extracting and articulating key ideas.

The above strategies should be taught from the early stages of reading, not just after “basics” are mastered. It is critical that students learn to use the strategies flexibly and in combination—for example, cooperative learning can be effective, with students posing questions, summarizing information, and modeling comprehension strategies for each other. Moreover, students should receive instruction on these strategies that includes direct explanations of the strategy, modeling by the teacher, guided practice using the strategy, and the application of the strategy in reading texts.

### *Technology*

There are several ways in which technology can provide direct instruction in comprehension strategies, including the ability to:

- provide hypertext and hypermedia that includes scaffolding of children’s text comprehension to support their learning, such as clarifications, summaries, concept maps, and key questions related to specific parts of the texts;
- provide embedded prompts that ask students to answer questions, add to concept maps or other graphic organizers, or summarize information, and online tools, such as a word processor or a concept mapping tool, to support their work; and
- encourage active reading by providing scaffolding options to read words aloud, provide definitions, explain concepts in texts, and provide visual aids. These supports help students experience successful reading, provide learning opportunities within the context of meaningful texts, make reading more engaging, and encourage the active use of comprehension strategies.

### *Research*

A growing body of research supports the value of computers, with well designed software, to support comprehension instruction.

In one of the first extensive studies of interactive texts, children in kindergarten through third grade used an interactive basal reader that featured synthesized speech, animations, definitions, pictures, and other tools (Higgins & Boone 1991). During the first year, students at three of the four grade levels significantly outperformed their counterparts in classrooms using the traditional basal readers. In a British study, Medwell (1996) found that early readers increased the accuracy of word recognition and text comprehension significantly when they used electronic books; peers using paper copies of the same books did not show the same gains, even with teacher support. The value of this type of technology is further supported by a study by Matthew (1997), who found that repeated use of electronic books increased early readers’ abilities to retell stories they read.

Lewin (1997) found that children using electronic talking books were able to read more independently possibly because the computer provided them with cues to cross-check meanings, and the colorful illustrations and animations motivated the children to use the program on their own. The children were also able to develop effective decoding strategies using the various components of the software, allowing them to read more of the text on their own. Electronic books have also been found to have value with older children who have learning disabilities. An early study of this technology found that upper elementary students with learning disabilities could dramatically improve their comprehension and word recognition skills by working with electronic talking books (Olson, Foltz, & Wise 1986); later research found that this held true for many students in need of remedial reading instruction (Wise,



Olson, et al 1989; Lewin 1995). Olofsson (1992) found that learning-disabled upper elementary students—particularly those above grade four—improved substantially in overall reading ability after working with software that used synthetic speech.

Children who repeatedly use electronic talking books begin to rely on multiple sign systems for meaning, including the expected sounds of words and the images on the screen (Harste 1994; Rowe 1994). Equipped with additional tools to decode the text, students can increase their overall comprehension of the books.

The NRP report stated that, although little research is available, “the application of hypertext concepts to reading and reading instruction seems to have a great deal of potential” (p. 6-9). Hypertext—interactive text that is searchable and contains links to other documents—has long been one of the fundamental components of the World Wide Web. Increasingly, software developers are relying on this technology to enhance text for early readers. Hypermedia is essentially a combination of hypertext and multimedia; in addition to linking documents to one another, software developers can also interlink animations, sounds, movies, and pictures. In elementary reading software, hypertext and hypermedia can enrich text with pictures, sounds, and animations to aid comprehension; change the nature of the story by creating nonlinear story paths for children to follow; and provide supplementary resources such as glossaries, pronunciation guides, or more in-depth information at the click of button. The means by which children can interact with hypertext vary, but most often, children can click on images and words to activate special features, find word pronunciations and definitions, or make choices for characters in the book. The ability of hypertext stories to directly involve students in choosing options represents a fundamental change in the nature of books, and creates a nonlinear story path in which the child has greater control (Karchmer 2001). In addition,

dictionaries, glossaries, encyclopedias, textbooks, and other traditional media can be transformed into hypertext with interactive features that allow students to cross-reference information, look up words, hear material read back to them, and access related supplementary material instantly.

Hypertext and hypermedia can also be effective in supporting text comprehension instruction. In particular, images and sounds may serve to clarify and ingrain meaning; children who interact with animated features in software demonstrate an enhanced ability to recount story events (Underwood & Underwood 1998). Older learning-disabled students were also able to enhance their understanding of texts by reading hypermedia versions of the material that included pictures, definitions, and digitized pronunciations (Anderson-Inman & Horney 1998; MacArthur & Haynes 1995). In addition, fourth-grade students reading long and difficult passages could answer comprehension questions more accurately when they had read the text on the computer. However, with shorter passages, the use of the computer did not impact overall comprehension in any notable way (Greenlee-Moore & Smith 1996).

A recent study by Dalton, Pisha, Eagleton, Coyne and Deysher (2002, see also Rose and Dalton, 2002) tested software with digital novels that provided:

- strategy instruction and embedded strategy prompts;
- student goal setting and self-monitoring;
- work logs that collected and stored students’ responses to strategy prompts;
- embedded assessments; and
- hypertext scaffolding to provide spoken text and vocabulary definitions when needed.



The students involved in the study were in middle school and reading at or below the 25<sup>th</sup> percentile. One group of students received computer-supported comprehension strategy instruction, while a control group received strategy instruction without the computer support. The results showed that the students in the computer-support group gained more than .5 grade equivalents in the pre-test to post-test comparison, while students in the non-computer group gained about .2 grade equivalents, a statistically significant difference. In addition, the scaffolds enabled students to read text that was well above their decoding level but which was age-appropriate in content and at their interest level, and the strategy prompts led students to read more strategically.

## **Other Potential Benefits of Technology in Reading Instruction**

### ***Technology and Students' Motivation***

One additional benefit of computer supported instruction is the effect technology may have on students' motivation to learn and to read. A study of kindergarten students using hypermedia-based software to teach letter recognition found that, although at-risk readers benefited the most from the software, all students were enthusiastic about using the computers and were motivated to explore and learn from the software (Boone, Higgins et al 1996). Presented with comparable paper and electronic resources, kindergarten and first-grade students preferred to wait for an opportunity to use the electronic version, even if a print version was immediately available (Mitchell & Fox 2001). An earlier study of such motivation found that the enthusiasm for learning in the target content areas persists even after the computers are taken away (Moxley & Warash 1990-1991).

Older students also showed an enthusiasm

for using reading software, even when they were otherwise reluctant to work on the reading concepts the software targeted. One research team posited that there might exist a unique and distinct group of students who responded to the software and made significant gains, but who would not have responded to teacher intervention (Nicolson, Fawcett, & Nicolson, 2000). Sixth-grade students assessing a hypermedia authoring project cited greater control over the nature of the work as a result of the technology as one of the most satisfying aspects of using the project (Finkelman & McMunn 1995). Similarly, third-grade students reflecting on CD-ROM storybooks noted that they especially liked the pronunciation features and definitions; they also recognized that the animations and sounds could both enhance and interfere with comprehension (Matthew 1996). With upper-elementary children, a study of hypermedia use in mainstream fourth- and fifth-grade classrooms found a number of secondary benefits in addition to students' gains in reading abilities and willingness to work collaboratively (Reinking & Watkins 1996). Classroom teachers reported marked increases in several relevant areas: the number of hours spent on recreational reading, the number of students holding library cards, and the number of students ordering summer book club memberships, among others. Parents of the students also reported that their children were more enthusiastic about reading. A similar project in six California school districts used a literacy program designed to teach reading through writing and reported instructional benefits for all students, including learning-disabled students and second-language learners. Again, parents reported increased reading and writing at home, and teachers and principals rated the technology highly (Casey 1994).

Taken together, these studies suggest that the increased flexibility, supports, responsiveness to students, and visual attractiveness of computer-presented hypertext and hypermedia may be valuable tools to help



increase students' motivation to read.

### ***Integrated Learning Systems***

The phrase *Integrated Learning System* (ILS) "is used to describe software programs that provide tutorial instruction in basic skill areas at several grade levels while keeping extensive records of student progress on networked computer systems. ILSs manage student registration, assign students to classes or classrooms, prepare reports on student progress for teachers, and manage student progress toward intended outcomes or objections" (Kulik, 2003). ILS software can include many of the capabilities of computers to support reading instruction described above, but how many capabilities are included, and how well they are designed, depends upon the particular system.

Kulik (2003) provides a recent summary of the research on ILS systems for reading instruction. He identified nine controlled evaluations, and finds that they show that the ILSs used did not result in significant improvements in reading scores: "The median effect of ILS instruction in the nine studies was an increase in reading scores of only 0.06 standard deviations, a trivial increment." That is, reading scores of ILS and control groups were nearly identical. This is consistent with the conclusion of an earlier review of ILS effectiveness by Becker (1994). However, Kulik also points out that the effect of ILSs might be much stronger if these systems were used as the developers planned. Students typically spend only 15% to 30% of the recommended amount of time on ILS instruction.

### ***Reading Management and Assessment Tools***

A number of products are designed to record the books that students read, provide rewards that motivate students to read more, provide tests to assess students'

comprehension, and provide useful data to teachers about individual students and the overall class. Topping (1999) summarizes the research on the mostly widely used of these products, Accelerated Reader, while Labbo (1999) raises important questions about this research. While Topping notes that the research generally reports positive results, he also notes that most of the research does not meet the NRP research quality criteria and therefore does not provide evidence of causal connections between the use of the software tools and impact on students' reading. Topping concludes his analysis by emphasizing that the critical factors are whether the teachers receive adequate professional development in the effective use of the technology and then implement it well in their classrooms, not simply the availability of the technology.

### ***Word Processing and Reading Instruction***

Instruction in reading and writing is often intertwined. Since both are dependent upon students' abilities to work with written language, they tend to develop together and reinforce each other. In fact, some approaches blend reading and writing, using children's own writing as part of reading instruction. In addition, writing is a path to reinforcing phonics skills and increasing vocabulary. Therefore, research on the use of technology to enhance writing instruction at the elementary level is also relevant in this report.

A meta-analysis on technology and writing instruction by Goldberg, Russell and Cook (2003), summarizes the research findings in this area. After identifying 99 research articles published from 1992-2002, they determined that 26 met their standards for research, which were consistent with those of the National Reading Panel.

This meta-analysis focused on the impact of the technology on three major variables in



children's writing: quantity of writing, quality of writing, and frequency of revisions during the writing processes. In each case, the studies reviewed compared these variables for students who used word processors in writing instruction and those who did not. The key findings show that students who write with word processors, as compared to students who write with pencil and paper, tend to produce longer and higher quality passages, and make more changes to their writing between drafts. The differences in quantity and quality were larger at the middle and high school levels than at the elementary level.

These conclusions are consistent with another recent summary of the research by Kulik (2003), who concludes "For two decades, then, evaluation studies have been reporting that students who use word processors for writing compositions demonstrate superior writing skills in later follow-up tests of writing skills." Kulik also points out that while the effects are educationally meaningful, they are not usually dramatic in size, with typical studies showing an increase of about 0.3 standard deviations, equivalent to an increase from the 50<sup>th</sup> to the 62<sup>nd</sup> percentile on a writing test. However, the size of the effect may increase as the technology becomes more readily available, the software improves, and teachers learn more about using word processing effectively in teaching children to read and write.

### **Making Decisions about Technology in Reading Instruction**

Our review of the research on technology and teaching children to read leads to the conclusion that multimedia digital technology, with capabilities such as hypertext, text-to-speech conversion, and speech recognition, has significant potential to enhance reading instruction at the K-6 level. This potential may be of the most value for students who have difficulty in learning to read, since the technology can help provide

appropriate levels of activities, repetitive practice, individualized feedback, supportive scaffolding, and detailed record-keeping to inform instructional decisions. Therefore, technology can help teachers provide more of the individualized instruction that children with reading difficulties need. However, the research on technology and teaching children to read is still in its infancy, especially in regard to technologies, such as speech recognition, that have only recently become affordable for use in schools. The existing research findings are based on small-scale studies, in particular contexts, so it is difficult to know whether they generalize to a variety of schools, students, and teaching approaches.

Our conclusions are consistent with those of the National Reading Panel, which found that: "The rapid development of capabilities of computer technology, particularly in speech recognition and multimedia presentations, promises even more successful applications in literacy for the future" and "There has been relatively little research in this important area and, consequently, many unanswered questions remain."

Educators responsible for decisions about classroom practices will find these conclusions to be encouraging about the potential of technology, but also very limited in their usefulness. The available research does not provide much information to help educators decide about specific technologies to use in specific ways within specific instructional approaches for specific groups of students, so the critical question -- *How can we make informed decisions about effectively applying technology in reading instruction within our school?* -- remains to be answered.

Research on technology to enhance instruction across grade levels and content areas consistently yields several important points about the effective use of technology, which provide some guidance in making decisions about technology in K-12 reading instruction (Kleiman 2000; Sun, Heath, et al





2000). Critical points to consider include the following:

1. The technology needs to be a good fit to the overall instructional program, complementing and extending the existing curriculum. Technology requiring major changes in approaches by teachers generally does not succeed in improving students' learning; therefore, the match of the technology options to the schools reading program is a critical consideration.
2. The technology must address critical goals and needs in order to be worth the cost and the effort involved. Therefore, decision makers should consider questions such as: *which components of reading instruction need to be strengthened in our school?* and *Are there specific groups of students who are not learning to read well?* Then the technology options should be reviewed for whether they might help address the critical needs of the school.
3. Identifying potential software, web resources, or other technologies that fit the instructional program and address critical needs can be challenging. Pereus (2002) provides useful recommendations about the process of selecting software. Websites that provide information to help decision makers with this task are listed in the table below:

The International Reading Association Electronic Classroom website (<http://www.readingonline.org/electronic/electronic/index.asp>), which is part of their Reading Online site, is "dedicated to sharing effective practices and new developments related to the intersection of literacy with technology." Example recent articles include Teacher Wisdom Stories: Cautions and Recommendations for Using Computer-related Technologies for Literacy

Instruction, reprinted from the *Reading Teacher*. Additional resources can also found on the International Reading Association Focus on Technology website (<http://www.reading.org/focus/tech.html>).

The What Works Clearinghouse (<http://www.w-w-c.org/>) was established in 2002 by the U.S. Department of Education's Institute of Education Sciences to provide educators, policymakers, researchers, and the public with a central, independent, and trusted source of scientific evidence of what works in education. Interventions on Early (K-3) Reading is the first topic to be addressed (<http://www.w-w-c.org/topic1.html>). Two reports are being prepared, the first on interventions for students with beginning reading difficulties and the second on interventions for general beginning reading students. Technology interventions should be included in both. The first report will be released during Winter 2004 and the second during Spring 2004.

The Metiri Group (<http://www.metiri.com/>) is providing reviews of the research on specific products to determine "technology solutions that work". They have a collection of useful reviews of specific technology products to enhance reading instruction, but the site is accessible only to schools and districts that pay a membership fee.

The LD Online website focuses on resources for teachers and parents of students with learning disabilities. The technology pages review products and applications of technology for language arts and other content areas ([http://www.ldonline.org/Ld\\_indepth/technology/technology.html](http://www.ldonline.org/Ld_indepth/technology/technology.html)).

The Children's Literature Web Guide (<http://www.acs.ucalgary.ca/~dkbrown/index.html>) provides Web resources related to books for children and young adolescents.

The International Children's Digital Library (<http://www.icdlbooks.org/>), provides a collection of children's books from around



the world freely available to children, teachers, librarians, and parents via the Internet. The goal of this project is to create a collection of more than 10,000 books in at least 100 languages.

The CAST web site (<http://www.cast.org>) offers a variety of resources, including an online version of the book *Learning to Read in the Computer Age*; information about CAST products, such as eReader which converts text-to-speech for any electronic text; summaries of research on technology and reading; and descriptions of the principles and applications of Universal Design for Learning.

The SEIRTEC News\*Wire issue on Technology in Reading Instruction provides information about a variety of ways schools are using technology to enhance reading instruction (<http://www.seirtec.org/publications/NewsWire/Vol6.1.pdf>).

4. There are many factors that must be considered to implement technology effectively (Kleiman 2000; Sun, Heath, et al 2000). Support and guidance from administrators is always a critical factor (eMints, 2002). The ready availability of sufficient and reliable technology is, of course, always essential; technology cannot be integrated into the curriculum unless sufficient computers are available and teachers can rely upon them working. Professional development for the teachers on the specifics of integrating the technology into the curriculum is another critical element, one which is often not given sufficient attention. In many cases, the implementation approach used in a research study is not replicated in schools that later use the products studied, thus the research results may not apply. For example, Topping (1999) and Labbo (1999) point out that the effectiveness of tools such as Accelerated Reader depends upon how they are implemented within the overall reading instruction program and on the professional development provided for teachers.

5. Since, in most cases, definitive research about specific technology tools and techniques will not be available, decision makers will need to base decisions upon the knowledge and experience of practitioners to determine the potential value of technology applications for reading instruction. In doing so, it is important to blend the practitioner wisdom of elementary teachers, reading specialists, special educators, and instructional technology specialists to reach the best possible decision. It is also valuable to pilot potential uses of technology in a small number of classrooms to check whether the potential of the technology can become a reality within your school.

6. Reading instruction is a major focus of federal and state education policies, substantial funding is being allocated to research in this area, and new technology applications are being developed; therefore, the resources and information available about technology to enhance reading instruction will grow dramatically over the next few years. The websites listed in the above table will enable you to make sure that your decisions are based upon the most up-to-date information.

## Conclusions

With the national emphasis on improving children's reading, the positive results shown so far in the research on technology and reading instruction, and the advances in the technology widely available in schools, we anticipate the rapid development of new applications of technology to support teaching children to read, along with a major increase in the research focused on the impact of these technology applications in helping children learn to read. While currently limited, the available research does point to many exciting possibilities for technology to enhance reading instruction (as summarized in appendix A) and suggests that there is great potential ready to be



explored by schools, technology developers, and researchers.

While the available research shows that technology does have the potential to enhance reading instruction, decisions about the effective uses of technology need to be based on an understanding of the school or district reading program synthesized with an understanding of the potential uses of technology and a careful analysis of the alignment between the needs of the reading program and the capabilities brought by the technology. Technology can help make a good reading program more effective, in the ways described in this article, but its value depends upon the quality of the overall reading program and the thoughtful implementation of technology to enhance reading instruction.



## Appendix A: Linking Teaching Recommendations and Potential Uses of Technology

Phonemic Awareness Instruction	
<i>Teaching Recommendation from National Reading Panel Report</i>	<i>Potential Uses of Technology to Support the Teaching Recommendation</i>
Use sound blending and word segmenting activities	Computer-based drill programs using digitized speech
Adjust activities to the child's level of phonemic awareness	Software that can analyze students' responses and individualize the practice set presented to each student
Teach sounds with the corresponding letter(s) of the alphabet	Multimedia capabilities to link sounds and letters
Use small group instruction	Computer-based games incorporating phonemic awareness, such as rhyming games, designed for two or more children to play

Phonics Instruction	
<i>Teaching Recommendation from National Reading Panel Report</i>	<i>Potential Uses of Technology to Support the Teaching Recommendation</i>
Teach direct and systematic letter-sound correspondences	Software to provide direct instruction and drills on letter-sound correspondences, while using systematic approaches to cover all the common correspondences
Adapt phonics instruction to individual needs based upon assessments of student knowledge of letter-sound correspondences	Software that can analyze students' responses and individualize instruction and practice
Combine phonics instruction with phonemic awareness activities, learning to recognize and write the letters, listening to stories and information texts read aloud, students' reading simple text, and writing	Software combining multimedia capabilities to link sounds and letters  Multimedia and hypertext to scaffold phonics within context of stories  Talking word processors to link writing and phonics



<b>Fluency Instruction</b>	
<b><i>Teaching Recommendation from National Reading Panel Report</i></b>	<b><i>Potential Uses of Technology to Support the Teaching Recommendation</i></b>
Model fluent reading and then have students read the same text aloud	E-books to provide models of fluent reading that are always available and under students' control (for example, to have sentences repeated)
Provide students with opportunities for repeated oral reading with support (for example, help with unknown words) and feedback	Hypertext designed to scaffold early reading to provide support for students, such as pronouncing words and providing definitions
Use audiotapes, tutors, peer guidance, or other means to provide both modeling of fluent reading and feedback	E-books and hypertext to provide modeling of fluent reading, supports for and feedback on students' own reading
Provide students with opportunities to practice reading with a high degree of success (for example, give students books in which they can read 95% of the words)	Hypertext to provide scaffolding enabling students to succeed in reading a larger variety of texts (especially important to enable children reading below their age level to read texts with appropriate and engaging content)

<b>Vocabulary Instruction</b>	
<b><i>Teaching Recommendation from National Reading Panel Report</i></b>	<b><i>Potential Uses of Technology to Support the Teaching Recommendation</i></b>
Encourage a wide variety of experience with written and spoken language	Technology ranging from reading hypertext to exchanging emails to creating web logs
Teach key vocabulary words directly	Software to provide direct instruction and practice with vocabulary
Teach word learning strategies, such as the use of the dictionary and thesaurus; the use of suffixes, prefixes, and roots; and the use of context clues to figure out the meanings of words	Web-based and CD resources  Software that provides direct instruction and practice using word learning strategies
Encourage students to make repeated use of new words in different contexts, including reading, discussions and their own writing	Technology used to provide a variety of opportunities for students to use new vocabulary words in both reading and writing





<b>Text Comprehension Instruction</b>	
<b><i>Teaching Recommendation from National Reading Panel Report</i></b>	<b><i>Potential Uses of Technology to Support the Teaching Recommendation</i></b>
Help students use specific comprehension strategies, including monitoring comprehension, using graphic and semantic organizers, generating questions and seeking answers in the text, recognizing story structure, and summarizing the text	Software scaffolds to support students decoding, vocabulary, and use of comprehension strategies.  Software tools used to create graphic and semantic organizers and summaries of text
Provide direct explanations of the comprehension strategies, modeling, guided practice using the strategy, and the application of the strategy in reading texts	Software to present explanations of strategies, models of their use, guided practice, and opportunities for student to apply them
Teach text comprehension strategies from the early stages of reading, not just after “basics” are mastered	E-books and hypertext capabilities used to scaffold students’ phonics, vocabulary, and fluency skills - making it more feasible to teach comprehension skills before all the other components of reading are mastered
Set up cooperative learning opportunities where students pose questions, summarize information, and model comprehension strategies for each other	Software that provides opportunities for collaborative work incorporating comprehension strategies



## Appendix B: List of Resources Reviewed for Relevant Research

### Major reading research journals:

Reading Research Quarterly\*  
Reading & Writing Quarterly\*  
Reading Research and Instruction\*  
Reading and Writing: An Interdisciplinary Journal

### Other journals publishing research on computers and reading instruction:

The Computing Teacher\*  
Reading Online\* (*online journal*)  
Reading Improvement\*  
The Reading Teacher\*  
Reading: Literacy and Language  
Journal of Research in Reading  
Journal of Literacy Research  
Reading Psychology  
Journal of Computing in Childhood Education  
Journal of Educational Computing Research  
Computers in Human Behavior  
Journal of Reading Behavior  
Journal of Learning Disabilities  
Journal of Experimental Child Psychology  
Scientific Studies of Reading

### Summaries of research

Annual Summary of Investigations Relating to Reading  
The Handbook of Literacy and Technology  
The Handbook of Reading Research  
The National Reading Conference Yearbook  
The National Reading Panel Report

*\*These journals were searched by hand for research appearing in the past three years. All other journals were searched electronically.*



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